On the

Ventricular Epithelium of the Frog's Brain.

by

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— A Thesis —

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by

[illegible]

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In the July number of the Johns Hopkins University Circulars for 1888, there appeared a short abstract – "The Ventricular Epithelium of the Frog's Brain." The following paper is the detailed account of that abstract. Before proceeding to discuss the methods and results of the research described in the work a brief account of the results reached by previous investigators is desirable.

In 1844 Adolphe Hannover (1)*, who was the first to study the Frog's brain with the microscope, stated that all the ventricles of the brain are lined by conical, ciliated epithelial cells, from whose deeper ends long fibres extend toward the periphery. He considered the cells, not as epithelial, but as true central nervous cells.

Alphonse Blattmann (2) in 1850 describes the walls of the ventricles as being lined with ciliated

* The numbers refer to the Literature at the end of the paper

epithelium:

[illegible], in 1837, says the brain cavities are lined with ciliated epithelial cells.

In 1864 E. Reissner, in his excellent description of the central nervous system of the frog, says in reference to the epithelium,— in the central canal of the spinal cord the cells are cylindrical, spherical or spindle shaped. It is uncertain whether these cells are ciliated or not. From the tips of the cells, the bases being turned towards the cavity of the ventricle, long processes run out into the grey substance. The thickness of the epithelial layer is 0.036μ — an isolated cell is in length = from 0.024μ – 0.036μ; in breadth 0.005μ – 0.008μ — the nuclei have lengths from 0.006μ – 0.012μ. Frequently the nucleus possesses no nucleoli but [illegible] cells. In the sinus rhomboideus the cells are much like those of the central canal — the

variations which occur are mostly in size, seldom in form. In several places, as in the roofs of the third and fourth ventricles, the long epithelial cells pass into flat cells. From the inner ends of these cells processes can be traced far into the brain. [illegible] [illegible] and in thickness is seen bordering the [illegible] cells – from this seam project clusters [illegible] employing cement or a little chalk. Ries [illegible] surface in order to observe the movements of the cilia. The cavities of the medulla and the rest of the brain are lined by cells similar to those just [illegible] give a striated appearance to the brain.

Schöne (S. Bod.) denies the presence of an epithelial lining to the central canal of the spinal cord – the so called lining is an optical [illegible] ([illegible])

In 1869 *Ludwig Stieda* published his work on the nervous system of vertebrates (1). He says in speaking of the epithelium – The central canal of the spinal cord is lined by epithelial cells which are cone shaped, the bases being turned towards the cavity. The cells measure at thier bases in breadth .004μ – in length about .04μ. The nuclei are large, round or oblong, and .006μ in length. From the cells bordering the anterior end [illegible] of the canal fine fibres or processes run off, which processes become attached to similar processes of the pia mater. The cells bordering the lateral regions of the canal have processes shorter and finer. The brain cavities, like the central canal, are lined by a single layer of cylindrical epi-thelium. A long process runs out from the tip of each cell. At certain regions of the brain the epithelium changes in character. Wherever pia mater only covers the ventricle – as in the *ventriculus*

[illegible] ,

[illegible], under the [illegible] [illegible] — the epithelium lining the surface of the [illegible] facing the ventricular cavity becomes flattened.

In another publication (?), 1875, Stieda describes the epithelium of the [illegible]. In the [illegible] part of this animal the cells are not regularly arranged around the central canal but are in groups. The cells are of two kinds — the one [illegible] with a long [illegible] the other [illegible] shaped. The nuclei of these two kinds of cells lying [illegible] [illegible] cells lying farther from the canal, give the appearance of a double row of cells, whereas there is only a single layer. [illegible] measurements can be [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] In the fourth ventricle the cells are regularly arranged, are cone or spindle shaped with their bases towards

the ventricle. The cells vary in size from .021μ – .024μ; in breadth are about .018μ. The relation of cone and spindle cells is the same as in the central canal – the long necks of the spindle cells are inserted between the cone cells. The epithelium of the other ventricles resembles that of the fourth ven-tricle.

Stieda in describing the central nervous system of the tortoise (10) says, – in the cord he could not establish the connections between epithelial processes and the pia mater as exists in the frog. The cells are small, ill-defined, and possess nuclei of from .008μ–.009μ in size. The structure of the cell and the presence of cilia could not be made out. The majority of the cells lining the ventricles are cylindrical. cone and spindle cells are also found. Cells vary in the different portions of the brain – all grades of transitional forms can be seen. All the cells are ciliated.

(10) [illegible]

side. They consist of a combination of pia mater and epithelial cells. The pia becomes much folded and the folds are lined with cells which are continuous with those of the ventricles of the brain. [illegible] these folds [illegible] are not ciliated.

[illegible] published his paper in 1872 [illegible].
He says that the epithelial cells of the ventricles and of the central canal form a continuous layer, are not flattened in shape, but are round. The cells of the ventricular epithelium send out long processes. In the central canal the cells on the ventral side are much larger and possess much longer processes than those on the dorsal side.
[illegible]
[illegible] epithelium. The cells on the ventral side are much larger and possess longer processes than those on the dorsal.

[illegible] in 18[illegible] [illegible] declares that all

[illegible] of the central canal [illegible] that the long processes [illegible] terminate in the connective tissue.

Hoffmann, in 1878, agrees with Stieda and Reissner in their descriptions of the Epithelium of spinal cord and brain (11).

Mason (12) also, says that in the frog the epithelium of the ventricles of the brain and of the central canal of the cord consists of ciliated cells. From these cells processes go off to become continuous with the [illegible].

It is [illegible] [illegible] [illegible] 1886 [illegible] that the epithelial cells of the ventricles [illegible] of the central canal are connected by their processes with processes from glia cells.

Ciriotriner says (10) that the tendency of modern research is to show that the epithelium of the ventricles of the brain and of the central canal of the cord is of a nervous nature. Klausner

has shown that the processes from the epithelial cells of the spinal cord of Proteus anguineus can be followed, some into the posterior root, some into the anterior commissure. All the cells are ciliated, and possess large, oval nuclei having nucleoli. It is probable that the epithelium forming the ventricles is most intimately related to the nervous elements, the cells and fibres. All the ganglion cells of the central organ are derived from the epithelial cells though the transition from one form to the other is not clear. In [illegible] according to Hermes, large ganglion cells arise within the ventricular epithelium by the quick growth of certain cells. These cells then sink into the brain substance to become ganglion cells. [illegible] found that the processes from the epithelial cells and nerve fibres stained exactly alike with gold.

Methods of Investigation. In order to extract the brain and spinal cord of the frog from the cranium and vertebral column uninjured the following method was adopted. The frog used was the Rana [illegible] frog. The animal was killed with ether or chloroform. After removing the skin from the back and from the top of the head, ~~[illegible]~~, the dorsal muscles of the vertebrae were stripped off up to the base of the skull. With a pair of scissors the vertebral column was severed [illegible] spinous process of the vertebra with the forceps, it is easy to introduce a pair of scissors into the neural canal and [illegible] neural arches [illegible] vertebrae, working from posterior to anterior, lifting [illegible]. In this way the whole of the dorsal half of the vertebral column and of the cranium can be taken off leaving the brain and spinal cord absolutely uninjured. After

__Cutting__ the roots of the cerebro spinal nerves the whole central nervous system can be easily cut out, the brain and spinal cord is obtained were transferred to one of the usual hardening agents as Müller's fluid, Potassium bichromate, Corrosive sublimate, Nitric acid, or Boric acid.
For the purpose of staining, Hæmatoxylin Gaule's quadruple method, Hæmatoxylin, [illegible], [illegible], [illegible], [illegible], Golgi's silver nitrate method, and Gold chloride were used. The method which, perhaps, gave more [illegible] to [illegible] and spinal cord in 5% nitric acid for 2 hours, wash out well in running water for 1/2 hour, transfer to 30% alcohol for 3 hours, then to 50% for 2 hours, 70% for 1 hour; 80%—90% indefinitely: two days is enough. After hardening sufficiently, the brain and spinal cord were well washed in water and then soaked for 1/2 hour at least with a 2% solution of Potassium bichromate — [illegible]

was quickly washed in distilled water and transferred to a solution of Böhmer's hæmatoxylin. In this solution of Hæmatoxylin the specimen was kept for 2–3 days heating the solution each day for 1 hour up to 38°C. It was then well washed in water, dehydrated, [illegible], sections cut [illegible] in the usual manner. This method, a combination of those recommended by C. S. Minot and A. B. Lee, yields excellent stains of the epithelial lining of the brain. In ~~[illegible]~~ stained sections the surplus color can easily be removed with acid alcohol.

For the preparation of teased specimens Dogiel's method was followed with excellent results. The brain and spinal cord was removed from the cranium and vertebral column by the above given method. The ventricles and central canal were laid open so as to give free access to the reagent and then the whole was placed in a 1% solution of osmic acid for 18–24 hours — Then, after being thoroughly washed with distilled water [illegible]

placed aside to macerate in a little water for one week. The specimen was finally transferred to a mixture of one half glycerine, one half water for a day — then into pure glycerine.

Small portions of the brain were placed with a drop of glycerine under the cover glass supported by a bit of paper to prevent undue pressure. By tapping, or by giving a gentle sucking action to the cover glass by alternately pressing and relieving, the cells can readily be separated.

<u>Distribution of the Epithelium.</u> The epithelial layer of the frog's brain and spinal cord forms a continuous lining to all the cavities of the central nervous system. It is everywhere a single layer thick. Though forming a continuous lining, yet the character and size of the cells vary considerably. In the <u>lateral ventricles</u> (Plate XXII, figs. 1, 2, 3), at the middle region of the right and left surfaces of the cavity, the cells are regular

in shape and size and clearly in a single layer; at the dorsal and ventral angles of the cavity these cells become slightly larger, and are more irregularly arranged. From the tip of each epithelial cell a tail like process can be seen running into the brain substance where it becomes lost.
In the third ventricle, at the dorsal (except in the roof of the ventricle) and ventral portions of the cavity the cells are typical epithelial cells, Plate XXII, fig. 4, 5, 6.; in the middle region, however, these cells are larger, more elongated, apparently two layers deep, and, from their tips much stronger processes penetrate the brain substance. These cells lining the [illegible] surface of the [illegible] forming the roof of the ventricle are, in the [illegible], small, flattened, and apparently tailless. The columnar and cement cells of the lateral wall of the ventricle pass gradually into these epithelial cells. (Plate XXII, fig. 4.)
Stieda (6) and Mierzejewsky (7) [illegible]

the change – see extracts given above. In the region of the optic lobes (Fig. 7), the cells present very different appearances at different parts; – those lining the cavity of the optic lobes being small, regular, and not particularly noticeable; from them small tail processes run into the brain substance; – those cells lining the Aqueduct of Sylvius are more than twice as large, are much more crowded especially at the ventral angle of the cavity, and have [illegible] processes (Figs. 7 and 8). In the fourth ventricle (Figs. 7, 9, 10, 11) the cells lining the floor are comparatively large and possess long and strong processes – the cells of the roof of the ventricle are smaller and their processes are not so conspicuous. This apparently is the general rule – the epithelial cells on the ventral surfaces of the ventricles are larger than those on the dorsal see Mierzejewsky (?) quoted above. It is curious [illegible] (Figs. 4, 7, 8, 9, 10, 11).

The relation of the Epithelial cells to the Brain cells. — The most cursory examination of a series of sections from the brain of the frog will reveal the fact that there is a definite relation between brain cells and the epithelial lining. Passing from the forebrain backwards and beginning our examination with a section taken from the region of the [illegible] [illegible], Fig. 1, it will be seen that the cells of the brain are arranged not promiscuously but in [illegible] [illegible] concentric to the epithelium; the processes from these cells give the brain a striated appearance. More posteriorly in the [illegible] [illegible] the concentric arrangement is still more striking (Fig. 4). Here not only are the brain cells arranged around the epithelium, but there is a lateral portion of the epithelial lining which [illegible] [illegible] the [illegible] [illegible]. In ~~[illegible]~~ Fig. 4, this spot is shown on the lateral walls where the epithelium appears folded. — Fig. 5 ~~[illegible]~~ is a representation of the left surface at this point

the cells here are larger, more numerous and apparently in several layers. Compare this with fig 6 taken from the left side [illegible]. At this central region also, the processes are longer, larger and more numerous. Passing still more posteriorly in the [illegible] [illegible] arrangement is still seen — a central region in the epithelium about which the brain cells are concentrically grouped. Along this region, also, the cells [illegible] larger [illegible] in several layers and have longer processes.

In the region of the optic lobe (Fig 7) the relation of brain cells to epithelial cells is the same. The concentric grouping [illegible]. Close to the epithelial lining of the optic lobe cavity is a layer of brain cells; just beyond, a layer made up of fibres from cells and processes from the epithelium, next a layer of brain cells not so closely packed as the first layer; then another fibrous layer, then another cell layer, another fibrous, and so on, the

Layers becoming less and less definite until the sharp distinction between cell layer and fibrous is lost, and the cells and fibres become promiscuously mixed. In the Aqueduct of Sylvius the epithelial cells are of the same size and shape as those of the central region of the third ventricle [illegible] Figs 7 and 8 [illegible]. The processes from the cells can easily be traced into the brain substance for a distance nine or ten times longer than the cell. The central region of the Aqueduct of Sylvius is worth noticing (Fig 8). The epithelial cells can be most distinctly made out and their processes followed for an astonishing distance! Close beneath the epithelial layer lie little packets or groups of cells. The clusters contain varying numbers of cells. Each cell of the cluster sends out two processes - one goes to an epithelial cell and becomes united with it - the other penetrates the brain substance and becomes lost. Apparently these clusters and groups of cells are [illegible]

lining epithelial layer — the size and shape of the nuclei of both classes of cells, their [illegible] [illegible] connection with one another, i.e. [illegible] cell to epithelial cell, indicate that these cells of the [illegible] are closely related to brain cells, are probably intermediate between brain cells and epithelial cells; — that, being derived from the epithelial layer, they probably represent the half-way stage between epithelial cell and brain cell. The tail processes of the epithelial cells lining the ventricles of the frog's brain, are, therefore, the connections or the remnant of the connections existing between [illegible] * In the [illegible]

Figs 9, 10, 11) [illegible]

The floor of the ventricle is lined with large epithelial cells each sending out into the brain substance a long slender process [illegible]. In Fig. 9 ~~figure 11~~ the [illegible] and [illegible] in such a section to be arranged [illegible]

* See [illegible]

[illegible] Fig 11 will show the size, shape, and arrangement of the cells lining the [illegible] — the cells are smaller, more regularly set, and do not possess such pronounced processes.

[illegible]

[illegible] specimens and passing to a study of successfully [illegible] preparations, it will be noticed, as [illegible] has already shown for the epithelium of the axolotl (9), that there are several kinds of cells [illegible] readily be found. The cells of the epithelium may be conveniently described as consisting of two typical kinds — a columnar and a spindle like form. Between these two kinds there are intermediate [illegible]. Each presents many variations. On surface view a small bit of the epithelium shows a closely packed [illegible] presenting a polygonal area, and the spindle [illegible]

and their nuclei being recognized by oblong spots, or thick short lines scattered between the cells. The columnar cells (Figs. 17, 18, and 22.) [illegible] regular body; from the basal end of each cell there projects into the ventricular cavity a closely set cluster of cilia. Each cilium bears at its base, where it joins the cell, an enlargement. This row of enlargements is the cause of the so called "basal seam" when seen under a low power of the microscope. The protoplasm of the cell can be followed directly into the cilia. The other end of the cell tapers, more or less suddenly, into a long comparatively stout protoplasmic [illegible]

The other class of cells, the [illegible] (Figs. 12, 15, 18, 22, 23, and 25.) largely consists of an oval or oblong body. From this central portion the body tapers into two processes one going to the ventricle where it expands again at the surface into a small enlargement [illegible]

to the head is formed the rounded [illegible] of [illegible] and [illegible] the basal swelling. The other processes runs from the body of the cell and forms the long [illegible] [illegible] [illegible].

Between these two shapes of cells there is every degree of gradation. Cells are frequently found possessed of an extremely long and thin [illegible] process with a spindle [illegible] (Figs 18, & 25) others are seen whose [illegible] processes are scarcely at all contracted (Figs. 15, 20, 22,) then [illegible] found cells [illegible] with no [illegible] process [illegible] (Figs 18, 19, 21, 23, 27.); finally we reach [illegible] (Figs. 17, 18, 22 [illegible] 28) [illegible] cells [illegible].

An interesting modification of the [illegible] cells [illegible] is shown by figs. 13 and 14

central body, also, sends out two processes, the one running into the brain substance, the other extending towards the ventricle; the latter in its course expands so as to become spoon shaped, fitting nicely in between the cone shaped or columnar cells. On the external ventricular surface the spoon shaped process is seen the row of cilia.

As Stieda [illegible] showed that in the epithelium of the spinal cord of the axolotl the cells were in a single row, the appearance of a double row of cells being due to the nuclei being at different levels, so, here, the appearance of several layers of cells as seen in Figs. 4, 5, 6, 7 & 8, is ~~[illegible]~~ due to the different relative positions of the nuclei [illegible] of cells described [illegible] — see Figs. 15, 18, and 23. ~~[illegible]~~ [illegible] epithelium of the [illegible] of the frog's brain [illegible]

As to the size of the cells, Reissner's (41) measurements are approximately correct — length, .024 m – .036 m; breadth, .003 m – .008 m – length of the nucleus [illegible]

The tail processes mentioned so frequently above as extending from the tip of each cell into the brain substance deserve especial attention. It will be seen in referring to the historical portion of this paper that the majority of investigators announce that these tail processes are connected with the [illegible]. The results of carefully traced preparations, however, do not support such a statement. No cell has been isolated which did not possess a tail process - except, perhaps, those cells, mentioned above, which form the internal lining to the roofs of the 3rd and 4th ventricles. The processes vary much in size and length. They are small and delicate in the lateral hemispheres; large, strong, and long in the third ventricle; small and delicate in the cavity of the optic lobes; strong and well developed in the Aqueduct of Sylvius and the [illegible]

Figure

[illegible] These processes are frequently [illegible]

(Figs. 15, 18, 19, 24, 26.).

Successfully [illegible] show [illegible] . 2 [illegible] of [illegible] branches [illegible] brain cell. (Figs 16, 19, 23, 26 and 27 [illegible]). Though the tail processes are branched, [illegible] connection with two or more brain cells has not been [illegible]. Starting from the epithelial cells the tail processes penetrate the brain substance, branch, and, by at least one branch [illegible] with a brain cell — the epithelial cell is directly connected with the brain [illegible]

The same is true for all portions of the ventricular cavity — epithelial and brain cells are connected as well as indicated by the accom[illegible]

The brain and spinal cord of a frog was carefully removed, as in the method described above, and placed in a glass trough under normal salt solution. The cerebral hemispheres were cut open by a longitudi-nal slit through the dorsal [illegible]

[illegible] so as to expose the epithelium of the lateral ventricle. The same was done for the ventricles of the optic lobes, the aqueduct of Sylvius, the fourth ventricle and the central canal of the spinal cord — a continuous ciliated passage from the lateral ventricles down to the central canal was thus obtained. With the microscope, the cilia could now be seen in active motion. If, now, with a pipette, a drop of water containing finely ground carmine be placed in the cavity of any of the ventricles, a most interesting sight will be obtained. Some of the carmine particles, [illegible] in the water, are caught on the cilia. This affords an excellent means of watching the movements — [illegible] little particles of carmine are vigorously lashed to and fro. At a temperature of 15° C. the following [illegible] [illegible] [illegible]
a comparatively large carmine particle, a cilium in the third ventricle beat 180 times per minute.

No. 2 In the same field of the microscope [illegible]

close to No. 1; a cilium bearing a piece of carmine about 1/2 as large as that of No. 1 beat 120 per min. <u>No. 3</u> In fourth ventricle a cilium beat 108 per min. [illegible] No. 4 fourth ventricle cilium beat 96 per min. Carmine smaller than No. 2; <u>No. 5</u> fourth ventricle, 138 per min. carmine same size as that of No. 2.

The cilia of the cells of the spinal canal, also, beat at the rate of from 100 – 200 strokes per min. No such thing as a wave of ciliary motion could be observed passing along the ventricles, but all over the microscopic field cilia could be seen beating independently, some slowly, some quickly, frequently side by side at different rates. Each beat consisted of a quick vigorous stroke and a comparatively slow recovery. By carefully watching it was seen that the vigorous strokes were directed always posteriorly – consequently on watching the floating carmine particles a current of water was slowly drawn from the fore brain backwards. The

phenomena were observed in all the ventricles of the brain as well as in the central canal of the cord.

In no case was there evidence of the existence of limiting membranes, either external or internal, to the [illegible] lining of the ventricles (Fig. 28 Fig. [illegible]). The cells sometimes show a tendency to adhere by their bases, the ventricular ends, but this may be due to the presence of an adhesive substance, or to the interlocking of the hardened cilia – certainly no separate membrane was found nor was there any indication in the cells of a tendency to adhere by their other ends – their tips. *

Conclusions. 1. The epithelial layer of the frog's brain and spinal cord forms a continuous lining to the central nervous system. It is everywhere a single layer thick.

2. The epithelium of the [illegible] a central zone of cells about which the [illegible] are concentrically [illegible]

* The [illegible] spinal cord of the tadpole of the same species of frog was examined [illegible]. The results were identical with those given above.

3. The cells of the epithelium and of the brain are connected by processes which extend from the tips of the former.

4. The [illegible] varieties — the columnar, the spindle, and inter[illegible] cilia beat with independent [illegible]

Before closing, I would like to express my thanks to [illegible]
to Dr. Brooks
to [illegible] extended during the progress of this work.

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This bibliography is not a complete list of the work done on the central nervous system of the frog but it contains merely the most important papers which refer to the structure of the Epithelium of the [illegible]

Explanation of Plate XXII.

Fig. 1. Cross section [illegible] showing [illegible] — Nitric acid and Haematoxylin. [illegible]

Fig. 2. Upper or dorsal angle of the ventricle from Fig. 1. Leitz [illegible]

Fig. 3. Lower angle of ventricle. [illegible]

Fig. 4. Section across inferior portion of the third ventricle. Fig 4 General view. Leitz Camera obj. A. treatment same as Fig. 1.

Fig 5 Middle portion of right [illegible] wall from Fig 4. Leitz Camera D.

Fig 6 Lower part of same side. Leitz' Cam. D

~~Fig. 1. Cross section [illegible] of the third ventricle [illegible] obj. A [illegible]~~

~~Figs 2 [illegible] middle and ventral [illegible]~~

Fig 7. — Section from the optic lobes — showing optic lobe cavity and the [illegible]

~~Fig. 8.~~ [illegible]
Fig. 7 [illegible]

[illegible] th [illegible]

[illegible] th [illegible]

[illegible]

~~Pl. [illegible]~~ Fig 9 [illegible]

[illegible]

[illegible] cam. obj. A. The details of the structure of the cerebellum have not been dra[illegible]

Fig 10 – [illegible]

[illegible] – [illegible] Cam. Obj. D. [illegible] Fig. 9.

Fig 11 [illegible] 9.

[illegible]

~~[illegible]~~ Fig. 19 [illegible]

[illegible] ~~[illegible]~~

Shows ciliated epithelial cell branched process [illegible]

[illegible] on with brain cells. Dogiel's method.

15 and 18 [illegible]

12, 20, ~~and~~ 21, and 25 [illegible] ~~12, 20,~~ [illegible] Third Ventricle.

Figs 19, From lateral [illegible]

Shows ciliated epithelial cells, their processes and their union with brain cells.

~~Plate X~~ Fig. 28 Piece of the wall of the third ventricle shows the different classes of cells

Figs. 13 and 14. Cells from third ventricle, ~~(a) and (b) cells with spoon shaped protoplasmic process~~

Fig. 24. Isolated cell with branched process. Lateral Ventricle.

Figs. 12, ~~and~~ 17, and 22 cells of the columnar and spindle varieties. Third ventricle and aqueduct of Sylvius.

Fig. 23 Cells from 4th ventricle - spindle cells and a cone cell are shown the process from the cone cell unites with a multipolar brain cell Zeiss 4. D.

Fig. 27. Third ventricle. ciliated cell sends out the process which joins a brain cell Zeiss Cam. D.

Fig. 16. Optic Lobe cavity - Shows connection of epithelium cell to brain cell.

Fig. 26. Third ventricle - Isolated cell with branched process joining a brain cell.

FOLD OUT

Vita

Luther Clarence Wightman was born in Columbia S.C. Feb. 27th, 1859. He was prepared for College at a private school in Charleston S.C. At Wofford College, Spartanburg S.C. [illegible] course included the following;—in languages, Greek, Latin; in mathematics,—geometry, trigonometry, surveying, calculus;—in the sciences, physics; in the department of English Biology, Chemistry, [illegible]; [illegible], literature,—Ethics, logic and belles lettres. [illegible]; [illegible]. In June 1879 he graduated with the degree of B.A. After graduation, he taught for three years as principal of the South Lyons Academy, St. Matthews S.C. He was, then, in 1882, elected principal of the Summerville High School, Summerville S.C. where he taught for one and a half years. Resigning this position he entered, in the fall of 1884, the Biological and chemical Laboratories of the Johns Hopkins University. ~~where he studied in the Biological and Chemical Laboratories.~~